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A multifaceted approach to providing consumers consistent meat tenderness

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ABSTRACT

A comprehensive program of research on the physiological and genetic basis of variation in meat tenderness has been undertaken. Key processes of tenderization have been identified; intervention and testing protocols have been devised and evaluated, including calcium chloride injection and in-line tenderness testing/classification. Genetic loci influencing meat tenderness have been detected, and DNA markers developed to aid selection and eventual identification of the allelic variation underlying these effects. This combined effort is leading to management and production approaches to providing a consistent, tender meat product.

Keywords: tenderization; QTL; meat quality; calpain.

INTRODUCTION

Meat tenderness has been identified as one of the primary challenges of the U.S. beef cattle industry (Smith *et al.*, 1995). Although generally considered less of a problem in swine, recently a renewed emphasis has been placed on tenderness in pork (Wheeler *et al.*, 2000) as selection for lean growth has affected meat quality. Since the majority of sheep meat is consumed as young lamb in the U.S., there has been little concern about meat tenderness until the introduction in the 1980s of animals with the callipyge phenotype, which has a dramatic affect on tenderness (Koohmaraie *et al.*, 1995; Freking *et al.*, 1999). Consumers desire a consistently tender product, and a single undesirable experience related to tenderness can have significant impact on future product choice (Miller *et al.*, 1995). Average per capita red-meat consumption in the U.S. has recently begun to rise, after years of decline, due in part to the popularity of an "all-protein" weight loss diet. A potential key to capturing this increase beyond the end of the diet fad is to provide a consistently flavorful, tender product.

An important point of consideration is that the majority of meat sold to consumers, when properly cooked, has very acceptable tenderness characteristics. Despite this high rate of "success" from a tenderness perspective, consumer experience has resulted in their willingness to pay a substantial premium for beef that has been tested for acceptable tenderness (Boleman *et al.*, 1997; Looker and Fee, 2000). The U.S. Meat Animal Research Center (MARC) has pursued a multifaceted program in meat tenderness that seeks to understand the genetic, environmental, and physiological aspects affecting this trait, as well as pursuing methods to test and influence tenderness during meat processing. Although the majority of effort has been in cattle and sheep, we anticipate that the principles and methods identified have potential application in all meat-producing species.

Substantial progress has been made in understanding the basis of meat tenderization. First, it is clear that tenderization occurs as a result of small but significant changes in the muscle during postmortem aging of the carcass. If insufficiently aged, a majority of carcasses produce tough meat. Key structural proteins are degraded by specific protease systems during aging, decreasing the structural integrity of the tissue. Differences in the rate and extent of postmortem proteolysis are the primary determinants of meat tenderness, and it appears that the calcium-dependent protease (calpain) system carries out this proteolysis. Second, it appears that the genetics of the animal can have an impact on tenderness, as demonstrated by breed evaluation studies (Crouse *et al.*, 1989; Gregory *et al.*, 1994). In general, animals with higher percentage of *Bos indicus* breed background have increased incidence of tough meat. However, heritability estimates within breeds suggest that only 30-50% of the variation in meat tenderness is due to additive genetic factors, with the majority of variation due to environmental or other influences.

MARC has pursued a research strategy that includes both breeding and intervention approaches to consistently tender product. The germplasm evaluation (GPE) project at MARC is a long-term program that determines production values of different breeds, in part by large crossbreeding studies. Impact of breed composition on meat tenderness is one important component of this study. In addition, a gene-mapping approach to identify chromosomal regions affecting tenderness has been applied both to an indicus/taurus cross resource population and a double muscled/normal cross population that have been phenotyped by Warner-Bratzler shear force measurement.

Gene mapping studies at MARC have revealed two quantitative trait loci (QTL) that appear to affect meat tenderness (Keele *et al.*, 1999; Casas *et al.*, 2000). One QTL lies on bovine chromosome 15 (BTA15), and the other on bovine chromosome 29 (BTA29). Interestingly, both of these bovine chromosomes are related by conservation of synteny to human chromosome 11 (HSA11). Therefore, substantial effort has been directed toward comparative mapping of HSA11 and the bovine genome (Rexroad *et al.*, 2000; Smith *et al.*, 2000). In the case of BTA15, a number of microsatellite markers have been developed for use in narrowing the QTL region, as well as gene-related markers being placed on the map to aid in identification of positional candidate genes from the human map. Although no obvious candidate genes were identified and mapped, at least one gene, CALCA, a hormone involved in partitioning of calcium between serum and bone, has been

placed under the QTL "peak" of probability and represents a potential candidate gene affecting tenderness through activities limiting available intracellular calcium. In the case of BTA29, a positional candidate gene has been identified and characterized. This gene, CAPN1 (also known as CANP1, mu-calpain), codes for the member of the calpain family that appears to be the main protease responsible for meat tenderization. The bovine and porcine genes and cDNAs have been cloned and sequenced, and a number of sequence polymorphisms in the genes have been identified. These polymorphisms have been used to map CAPN1 in cattle, directly under the "peak" of probability for the location of the tenderness QTL. Further work is aimed at determining if allelic variation at the CAPN1 locus can be related to meat tenderness in other populations, and at identification of specific sequence variation underlying the effect.

The results of the QTL study underscored the influence of environment on meat tenderness. The significance of the QTL on BTA15 was highly dependent on slaughter group, demonstrating that under some conditions, the effect of the QTL allele could not be observed due to some overriding environmental effect. This result argues that manipulation of genetics is unlikely to be the total solution to the problem of variation in meat tenderness in the near future. Therefore, two additional approaches, intervention and testing, have been taken. Based on the principle that calcium-dependent proteases such as CAPN1 are the primary effectors of tenderization, trials were conducted to evaluate the impact of calcium injection (marination) on shear force (Landsell *et al.*, 1995; Wheeler *et al.*, 1996). These studies showed a direct, positive impact of calcium injection on tenderness, suggesting that injection of food-grade calcium chloride into meat is a viable method to insure a consistently tender product. Although studies suggest consumer acceptance of this practice would be high (Miller *et al.*, 1995), it has not been put into general application by the U.S. beef industry. Therefore, another approach has been evaluated that utilizes carcass testing and grading for meat tenderness (Shackelford *et al.*, 1997, 1999; Wheeler *et al.*, 1999). Carcasses were tested by removal of a steak at the 12th rib cross section, which was analyzed by shear force measurement after trimming, cooking, and sampling. Based on this measurement carcasses were graded as tender, intermediate, or tough. There was a high correlation of assigned class with tenderness measured after aging by slice shear force measurement and by trained sensory panel, demonstrating that sampling of the carcass prior to aging can predict carcass merit at the consumer level. The potential of this system to increase value of the meat product has been evaluated by consumer studies that show the willingness of consumers to pay a premium for meat marked as "guaranteed tender" based on this type of carcass evaluation (Boleman *et al.*, 1997).

The successes described in this report suggest that a multifaceted approach that integrates genetics, testing, and intervention, has the potential to substantially decrease variation in meat tenderness. As more is discovered about the genetic and environmental variables affecting tenderization, other approaches and improved breeding techniques may also become available. We believe this approach will lead to an overall program that can provide a consistently superior product for the discerning consumer.

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